AN ALGORITHM OF THE SIDELOBE LEVEL OPTIMIZATION FOR THE DUAL SHAPED SYMMETRIC REFLECTOR ANTENNA

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ABSTRACT

The algorithm of the sidelobe level optimization for the dual shaped symmetric reflector antenna with the aperture diameter $D > 20\lambda$ is presented. It is based on the method of the far-field pattern estimation by the aperture distribution. The maximal aperture efficiency is the criterion of the aperture distribution optimization on the condition that the far-field pattern estimation answers to recommendations ITU-R. Optimization parameters are defined by the function of the aperture distribution that is described as analytical function with shadow area at the center aperture, uniform area and transition regions.

INTRODUCTION

Modern communication reflector antennas with the high aperture efficiency for ground stations are to comply with international norms and parameters. If antenna for ground station operating with geostationary satellites put into commission after 1995 then its radiation diagram must satisfy to ITU-R recommendations.

Traditionally such antennas are designed by using of the geometrical optics technique to synthesize the reflector surfaces [1]. The resulting surfaces S_0 and S_{sr} (Fig.1) are determined by the solution of the system of differential equations when functions of the aperture power density $I(r) = f^2(r)$ and the primary feed pattern $F(\vartheta)$ are chosen. As a rule the ensuring of maximum aperture efficiency is the main requirement for the choice of the function described the aperture power density. Execution of ITU-R recommendations for the sidelobe level supposes a finding of amplitude distribution function $f(r)$ as a result of decisions of the pattern synthesis problem.

In this paper the choosing of the form of the amplitude distribution function is discussed and possibility of its parameters optimization for providing the specified sidelobe level without essential reduction of aperture efficiency is analyzed.

A DESCRIPTION OF THE METHOD

As known, the physical optic technique for the far-field calculations becomes equivalent to the aperture distribution method when the aperture diameter of the reflector antennas is $D > 20\lambda$. Therefor in this paper the sidelobe level evaluation is fulfilled valued by the aperture method, and the antenna gain is determined on the base of the aperture efficiency $\eta_a(f(r))$ calculation.

The amplitude distribution in the aperture of the axially symmetric dual reflector antenna may be expressed as the difference of analytical functions:

$$f(r)=f_1(r)-f_2(r)\ , \tag{1}$$

where

$$f_1(r)=\begin{cases}1, & r\le a_2\\ \exp\left(-b\left((a_2-r)/(a_2-1)\right)^2\right), & a_2\le r<1\end{cases}$$
$$f_2(r)=\begin{cases}1, & r<a_{\min}\\ \cos\left(\frac{\pi}{2}\left((r-a_{\min})/(a_1-a_{\min})\right)^2\right), & a_{\min}\le r<a_1\\ 0, & a_1\le r<1\end{cases}, \tag{2}$$

$r=R/R_{\max}$ is the normalized coordinate of the amplitude distribution function, $r_{\min}=R_{\min}/R_{\max}$ is the relative radius of the shadowed central area, a_1, a_2 are relative radii of intermediate areas, the coefficient $b=-\ln(f(1))$ define the field level at the edge of the aperture (Fig. 2). This type of analytical function is suitable for problem decision of the aperture efficiency optimization:

$$\eta_{a\max}=\max(\eta_a(a_1,a_2,b))\ . \tag{3}$$

However the expression (2) can't be used for the analytical calculation of the radiation integral $\mathbf{K}^A(\theta,\varphi)=\int_{S_1}\mathbf{E}^A\exp(jk\boldsymbol{\rho}\cdot\mathbf{i}_R)dS_1$, which is required for the estimation of the reflector antenna far field:

$$\mathbf{E}(R,\theta,\varphi)=-\frac{jk}{4\pi R}\exp(-jkR)\mathbf{i}_R\times(\mathbf{i}_z+\mathbf{i}_R)\cdot\mathbf{K}^A\ . \tag{4}$$

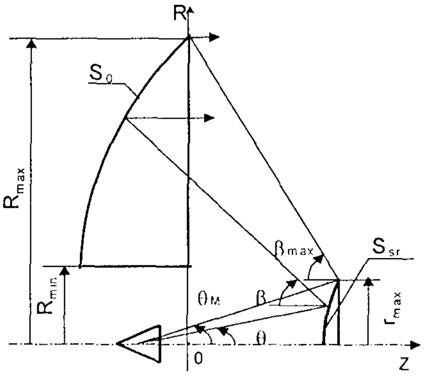

Fig. 1. Shaped feed system for the reflector

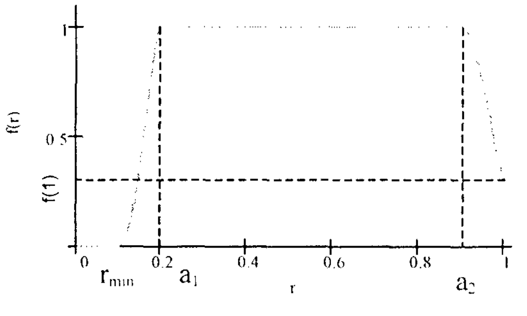

Fig.2. Amplitude distribution at the aperture

So the amplitude distribution function (1) is approximated as difference of series:

$$f_{ann}(r)=\sum_{l=0}^{L_1}A_l\left(1-r^2\right)^l-\begin{cases}\sum_{l=0}^{L_2}B_l\left(1-(r/a_1)^2\right)^l, & 0\le r<a_1\\ 0, & a_1\le r<1\end{cases}, \tag{5}$$

where A_l, B_l are approximation coefficients of functions $f_1(r)$, $f_2(r)$, accordingly. Matching points along radial line of the aperture coincide with zeros of Chebyshev polynomials $T_L(1-2r^2)$. This choice of match points allows minimizing the maximum error.

Substituting (5} into (4) and carrying out the integration using the properties of the Bessel function [2] we have the resulting expression for $\mathbf{K}^A$:

$$\mathbf{K}^A(\theta,\varphi)=\mathbf{K}_1^A(\theta,\varphi)-\mathbf{K}_2^A(\theta,\varphi),$$

$$K_{l\ 1}^{A}(\theta,\varphi)=2\pi R_{\max}{}^2\exp(ju\cos\varphi)\sum_{l=0}^{L}A_l 2^l\Gamma(l+1)\frac{J_{l+1}(u)}{u^{l+1}},\qquad (6)$$

$$K_{l\ 2}^{A}(\theta,\varphi)=2\pi(a_1R_{\max})^2\exp(ju_1\cos\varphi)\sum_{l=0}^{L_1}B_l\Gamma(l+1)\frac{J_{l+1}(u_1)}{u_1^{\ l+1}}.$$

where $u=kR_{\max}\sin\theta$ and $u_1=a_1u$.

When the geometrical optics syntheses of antenna surfaces is fulfilled for the amplitude distribution given by function (5), the expression (6) describes the far field without the loss of accuracy.

Resulting dependencies are presented on Fig. 3

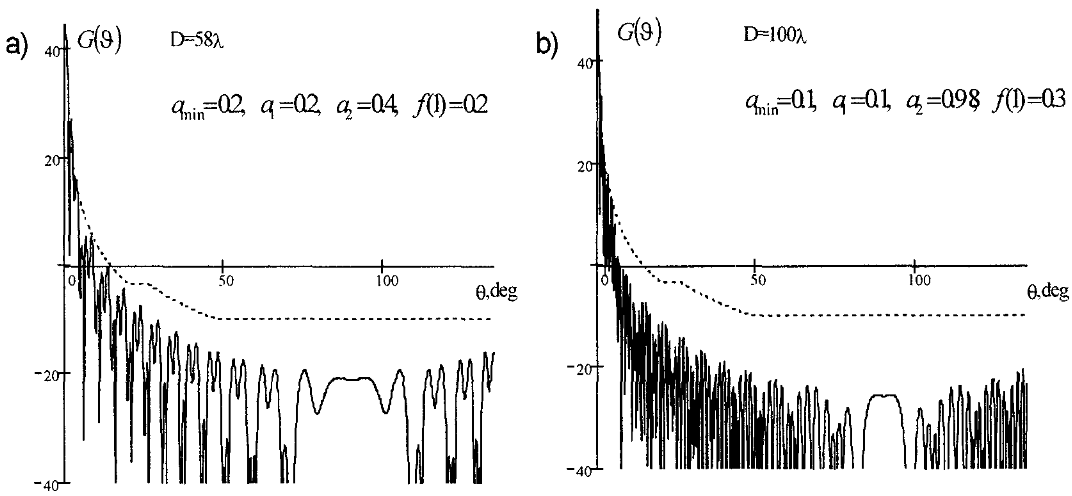

Fig. 3. Radiation pattern of the dual symmetric reflector antenna

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